Does glucose consumption affect attentional control? An investigation using the Spatial Blink Task

Research Thesis

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By

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Abstract

Previous evidence shows that cognitive functions such as memory are improved by glucose consumption, suggesting these functions are dependent on energy metabolism. However, it is not clear whether glucose influences attentional control. Attentional control is the ability to allocate attention to relevant information and ignore irrelevant information. In this study, we test the effect of glucose consumption on performance on a Rapid Serial Visual Presentation (RSVP) task. In this demanding attentional control task, participants identify a target letter of a specific color appearing in a series of rapidly presented letters in different colors. This task requires strong attentional control to focus on the target color and ignore irrelevant colors. A colored outline square surrounding the RSVP stream, the “distractor,” appears at different time points before or after the target letter. If the distractor matches the target color, the participant’s attention is captured, resulting in reduced accuracy. In this double-blind within-subject study, participants complete two sessions. In random order, participants are assigned a glucose drink and a placebo drink. Date replicate the capture effect and demonstrate that it extends into our modified paradigm. The results showed no effects of drink consumed on performance on the RSVP task. Glucose did not cause a faster disengagement from distractors. These results,combined with other recent studies, cast doubt on the relationship between glucose consumption and cognitive function (Kurzban, 2010).

Keywords: Glucose, Attentional Control, RSVP Task, Attentional Blink

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The ability to control attention is essential for strenuous and intensive tasks. For example, while taking entrance exams for college, graduate, and professionals, it is beneficial to be able to pay attention to only one question at a time instead of attempting to attend to all questions simultaneously. Students often attempt to enhance their ability to control attention and perform well on exams by ensuring their energy levels are high, by consuming high caloric foods. Folk wisdom holds that consuming foods high in glucose promotes better performance on cognitive tasks. To some extent, this has been supported by research: it has been previously shown that increased glucose consumption improves cognitive functions such as memory (Foster, Lidder, Sunram, 1998). However, it is unclear how glucose affects attentional control. In the current study, we investigate if glucose has an effect on attentional control and if so, how glucose affects attentional control.

Attentional Control

The brain is not fully capable of processing all stimuli simultaneously. It must select certain stimuli to attend and other stimuli to ignore. Therefore, some stimuli receive more detailed processing. It is the role of the attentional system to decide which stimuli should receive priority.

Attention can be shifted in a “bottom-up” salience-driven manner. That is, attention can be involuntarily captured in a “bottom-up” manner by salient information (Egeth & Yantis, 1997, Theeuwes 1991; 1992). For example, notifications on a phone are salient stimuli that capture attention. In addition, the allocation of attention can be influenced by prior learning. For example, attention may be preferentially allocated to rewarding stimuli (Belopolsky & Theeuwes, 2012).

Attention may also be guided in response to “top down,” goal-directed settings. In goal-directed attentional control, attention is voluntarily biased toward task-relevant features, which results in the prioritization of relevant information (Folk, Remington & Johnston, 1992). For example, if you were searching for a dime in a pile of coins, you might search according to the size of the coin. That is, you would have an “attentional control setting” for a specific size. Furthermore, people can switch attentional control settings regularly and flexibly to prioritize different “features”, such as colors or shapes (Lien, Ruthruff & Johnston, 2010). The ability to switch attentional control settings allows people to adapt their attention strategy to different goals. For example, it would be beneficial to be able to search for your friend’s yellow sweater at an Ohio State football game, but be able to switch your strategy at when looking for a friend in a field of dandelions.

Despite its advantages, one consequence of goal-directed attentional control is that attention can be involuntarily captured by stimuli in the environment that have similar features to the attentional control setting. One instance of this may be when you are searching for your mom’s car based on its red color feature. Your attention may be captured by a stranger’s red car passing by, and this may cause you to miss your mom’s car passing by. Folk et al. (1992) showed that when a distractor stimulus sharing the same property as the target occurs before the target stimulus, it can momentarily capture attention and slow attention from being allocated to the correct goal stimulus. However, when distractor stimuli did not share the same features as the goal target, individuals are able wereable to avoid capture (Folk, Remington, & Johnston 1992; Leber & Egeth, 2006).

The effect of glucose on cognitive processes

Many have speculated that cognitive functions, such as attention, rely on a continuous source of energy. According to Wenk (1989), cognition is improved through increasing glucose availability and utilization to the prefrontal cortex. Glucose is able to cross the blood brain barrier to enter the brain and facilitate many biochemical mechanisms in the central nervous system that affect cognition (Wenk, 1989). Additional studies have suggested that cognitive functions such as self-control rely on an adequate supply of glucose (Galliot & Baumeister, 2007). This implies that consuming glucose may facilitate cognition.

The relationship between glucose and cognition can be seen in healthy young adults. Glucose enhances peoples' ability to perform on memory related tasks (Benton, Owens, Parker, 1993). For example, in an experiment by Foster et. al. (1997), performance in short and long delay free recall and short and long cued recall tasks were significantly improved by an increase in glucose consumption, showing that glucose availability enhances memory performance. In another study using a "serial sevens" task, a demanding cognitive task which measures the ability to count down from one hundred by sevens, participants who received glucose were able to generate more responses (Scholey, Harper, Kennedy, 2001). This suggests that glucose is able to enhance performance by decreasing the time required to accomplish complex mental operations. These studies show that glucose is able to improve cognitive performance through improving memory and response time. Glucose may alsomodulate one's ability to override impulses and other self-control mechanisms. Demanding self-control tasks such as impulse control have been shown to deplete blood glucose levels, suggesting self-control tasks rely on glucose availability (Galliot & Baumeister, 2007).

With regard to attention, the results have been mixed. There is some evidence that glucose enhances individuals' ability to increase attention. For example, glucose facilitated performance in a Sustained Attention to Response Task, which measures individuals' ability to respond to relevant information and adequately ignore irrelevant information, (Birnie, Smallwood, Reay, &Riby, 2015). The authors attributed this finding to an improvement in focused attention measured by the amount of self-reported task-relevant thoughts. Another experiment by Brandt, Gibson, and Rackie (2013) investigated this using the Stroop task in which participants are shown color names written either in a congruent or incongruent color. In the congruent condition, the name of the color matches the color it is written in. In the incongruent condition, the word and color are mismatched (Stroop, 1935). The authors believe the incongruent condition of the Stroop task requires stronger attentional control because participants must ignore irrelevant information, the word, and only attend to relevant information, the ink color. This experiment found that participants who consumed a glucose drink had significantly reduced response times as compared against participants who received a placebo drink, althoughthere were no differences between the error rates in the two. But divergent evidence argues that glucose does not enhance attention in healthy young adults. Benton, Owens and Parker (1993) also used the Stroop task to investigate the effects of glucose consumption. Glucose did not have an effect on performance in either the congruent or incongruent conditions. However, in this study participants were not required to fast, so participants' glucose levels may have been at ceiling.

Combined, these studies show that it is not clear whether glucose consumption influences attentional control. Further, the mechanism by which glucose may influence performance is unclear. Although Brandt et al. (2013) found evidence for an improvement of control, the Stroop task does not allow us to differentiate different effects of control. For example, glucose may strengthen the engagement of attention on task relevant stimuli and reduce distraction from irrelevant stimuli. Alternatively, glucose may improve attentional control by helping individuals disengage from irrelevant information and attend to relevant information more rapidly.

The present study

The aim of the current study is to investigate the effects of glucose consumption on attentional control. We tasked participants with drinking both a placebo and a glucose drink in separate sessions and observed the effects of each on attentional control. We probed attentional control by using the contingent attentional blink paradigm from Folk, Leber, and Egeth (2008). In this task, based on the Rapid Serial Visual Presentation (RSVP) procedure, a rapid stream of letters is presented at fixation on a computer display (Reeves & Sperling, 1986). Participants are instructed to search for a letter in a particular color. Only one of the letters in the stream is in the target color. Additionally, a grey outline box surrounds the stream and briefly changes to a distractor color. This distractor can be the same-color (task relevant) or different-color (task irrelevant) as the target and it can be presented at various time points with respect to the target, referred to as “the distractor-target lag”. A lag of 1 indicates that a distractor is presented one serial position prior to the presentation of the target letter. Folk et al. (2008) showed that when a same-colored distractor was presented prior to the target letter, attention was momentarily captured by the distractor, which in turn momentarily impaired participants' ability to detect the target. The effect of the attentional capture was most strongly shown when the same-color distractor was presented 200ms (lag 2) prior to the target letter. As more time separated the presentation of the same-color distractor and the target letter, participants were better able to recover from the capture and return to the target letter, such that accuracy gradually returned back to baseline (see Figure 1a for the standard finding from the contingent blink paradigm). When the distractor color did not match the target color there was no attentional capture. Because attentional capture is not apparent in the different-color distractor condition, it suggests that the capture was contingent on the attentional control settings. Therefore, this is termed a contingent blink (Folk, Leber, &Egeth, 2008).

The contingent blink paradigm is an ideal tool to study the effects of glucose on attentional control because it requires strong attentional control to be able to identify the correct target and adequately ignore the distractor. Moreover the variation in temporal lags allows precise investigation into the differences in the effects of glucose across time.

Predictions

We predicted that if glucose influences attentional control, it may affect performance in one of two ways.

First, by a *faster disengagement* account, participants will be able to disengage attention rapidly from task-relevant distractors. This would allow accuracy to improve back to baseline more quickly (see Figure 1b). Previous studies have shown that there is variation across individuals in their speed of disengagement. For example, individuals with higher working memory capacity disengage faster than those with a lower working memory capacity (Fukuda and Vogel, 2009). Glucose may facilitate participants' ability to voluntarily disengage attention from distracters. The ability to rapidly disengage from distracting information and shift to relevant information may explain the speeded reaction times found in the Stroop task of Brandt et al. (2013).

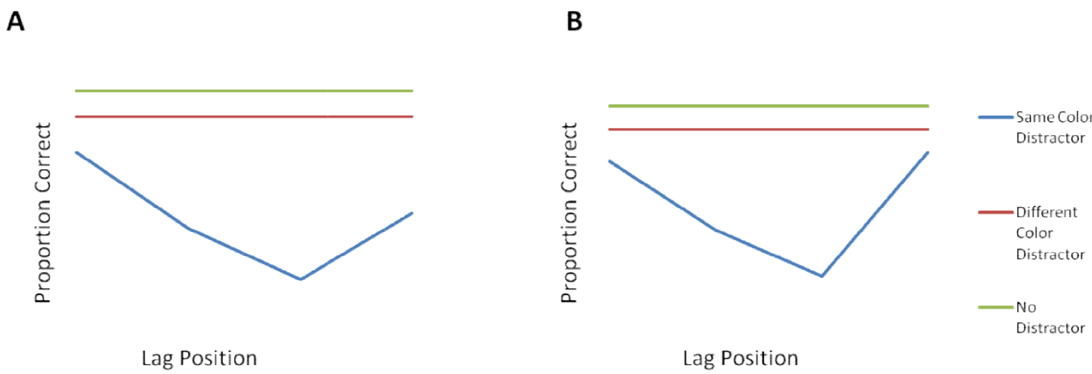

*Figure 1.***A**: In the placebo drink condition, we expect to see no change in proportion correct across lag positions in the no distractor and different-color distractor conditions. In the same-color distractor condition, we expect to see lower proportion correct, reflecting an attentional blink, at lag 2. **B:** *Faster disengagement account:* In the same-color distractor condition, an attentional blink occurs at the same time in the glucose condition as compared to the placebo condition. However, in the glucose condition, participants' accuracy reflecting the ability to disengage attention from the distractor and attend to the correct target returns back to baseline more quickly as lag position increases than compared against the placebo condition.

Second, by a *stronger engagement* account glucose may enhance individuals' ability to sustain an attentional control setting, strengthening their ability to engage with task-relevant information. One unique prediction of this account is that the strengthened control setting would also increase attention to the same-color distractor, paradoxically worsening accuracy. Glucose may increase an individuals' ability to exert effort (Galliot & Baumeister, 2007) and previous studies have shown that overexerting effort may lead to a stronger attentional blink (Olivers & Nieuwenhuis, 2006). Thus, in this current study, the strong attentional control may influence individuals to attend to the distractor that has features similar to the target, resulting in stronger attentional capture.

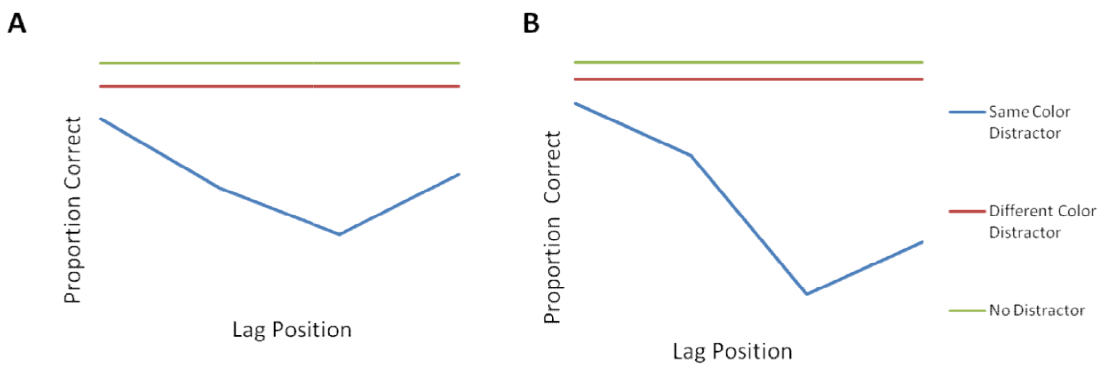

Figure 2. **A:** Figure 1 repeated for convenience. **B**: A deeper concavity same-color condition reflects a stronger attentional capture and therefore lower accuracy in the same in the glucose condition as compared against the placebo condition.

Methods

Participants

Participants were recruited from the student population at The Ohio State University. Participants received either introductory psychology course credit or $15 per 1.5 hour session for their participation. Participants ranged in from 18 to 25 years of age (mean age: 20.31; 15 female, 4 male). All participants reported normal or corrected to normal vision and normal color vision and gave informed consent. Individuals were asked not to participate if they had been diagnosed with diabetes or any disorder (e.g.

an allergy) that prevented them from consuming any of the drink ingredients. The methods of this experiment were approved by the institutional review board at The Ohio State University.

Materials

This experiment was run in a sound-attenuated behavioral testing room that was dimly lit. Stimuli were presented using Matlab software (Mathworks, Natick, MA) with Psychophysics Toolbox extensions (Brainard, 1997; Pelli, 1997) on an Apple Mac mini computer using a 24” LCD screen. An Eyelink DM-1000 eye tracker was used to collect information relevant to pupil data for a larger, ongoing project in the Cognitive Control Lab. Pupil data will not be reported in this manuscript.

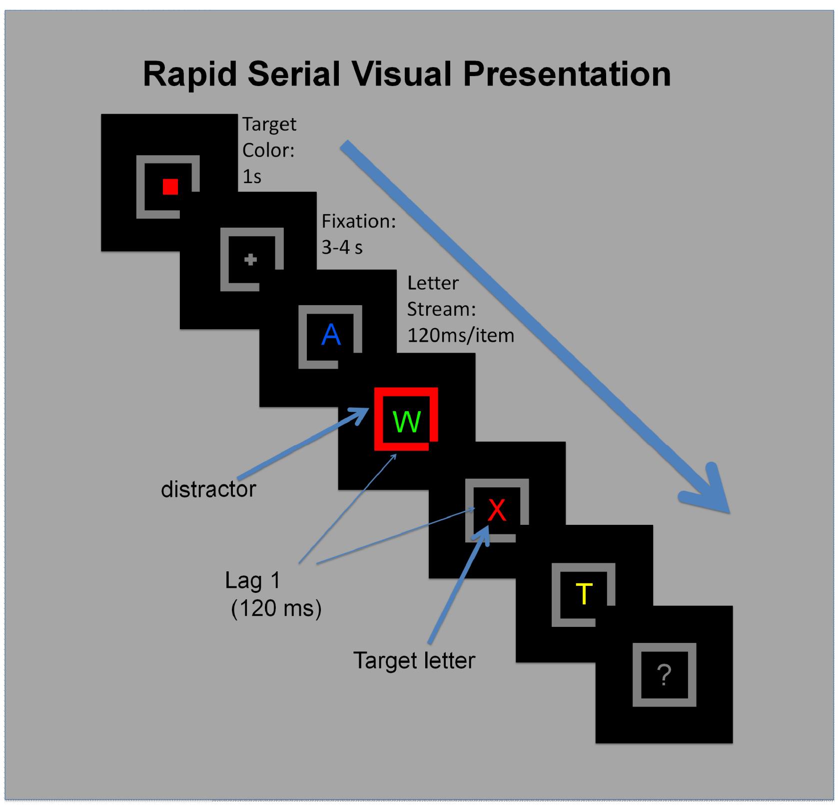

*Figure 3:*A visual representation of the stimuli and trial sequence.

Stimuli

A representation of the task stimuli is shown in Figure 3. The target color cue display consisted of a square (size: 0.864° by 0.864) that could appear in one of seven target colors: blue (RGB: 0,255,255), yellow (0, 255, 0), purple: (102, 0, 204), pink (255, 0, 127), orange (255, 128, 0), or dark blue (0, 0, 255). This was surrounded by a grey border(RGB (96, 96, 96) size: 2.38° by 2.38°, line thickness: .234°).The fixation display consisted of the same grey border with a fixation cross (.426° by .426°) in the center of the display. A stream of rapidly presented colored letters was then presented. The stream consisted of the following letters: A, B, D, E, G, H, K, L, M, R, S, T, U, W, X, and Z in Arial font, sized approximately about .430° by .864°. Each stream contained one letter in the target color.The other letters in the stream were presented in one of the non-target colors, inrandom order with the restriction that each was different from the previous color.

The distractor consisted of a color change to the outline boxsurrounding the letter stream. In the *same-color distractor* condition, the distractor was the same color as the target. In the *different-color distractor* condition, the distractor was one of the six colors other than the target color. In the no distractor condition, the outline box did not change color.

Drinks

Two types of drinks, a glucose and a placebo drink was administered. The drinks were matched in sweetness level and mouthfeel and were prepared prior to the start of each experiment by an experimenter who was not involved in data collection. Both drinks contained 6 ounces of diet Ocean Spray Cran-Mango [Cranberry juice concentrate, Mango juice concentrate, Citric acid, Pectin, Fumaric Acid, Ascorbic Acid (vitamin c) Sodium Citrate, Gum Arabic, Sucralose, Ester gum, Acesulfame Potassium, Red 40 and Blue 1] mixed with 6 ounces of water. Additionally, the placebo drink was supplemented with 6.5 packets of the artificial sweetener Splenda, which contains 77mg of sucralose per packet. The experimental (glucose) drink was supplemented with 39 g of Now Foods glucose powder.

Procedure

Drink consumption

This was a double-blind, within-subject study in which participants attended two separate sessions. The sessions were scheduled according to the participants' availability with at least one day between each session. Each session lasted 1.5 hours. During both sessions participants arrived at the lab between 8am and 11:30am. All participants were asked to not consume any foods or drinks besides water for at least 2 hours before each session. At the beginning of each session, participants were asked to read over and sign a consent form. Participants were assigned one drink per session. In random order, participants received either a glucose drink or a placebo drink. Neither the experimenter nor the participants knew which drink was assigned during which session. Participants were asked to finish consuming the drink within 5 minutes and continue to wait another 10 minutes before beginning the behavioral part of the experiment. During the 10 minute wait time, participants were asked to guess if their drink contained added sugar, rate their confidence level in their prediction on a scale from 1 to 5 with one being the least confident and 5 being the most confident, and report their energy levels on a scale from 1 to 10 with 1 being the lowest energy level and 10 being the highest energy level.

Behavioral task

Written instructions displayed on the screen and verbal instructions were given. Participants were told they would be searching for a target in a stream of rapidly presented colored letters. At the end of the trial they would be asked to identify the target color. Participants were also informed that sometimes the border of the box would change to another color before or after the target letter was presented. Participants were told the distractor would make it harder to detect the target, and they were encouraged to try to ignore it.

After the instructions, participants completed 10 practice trials. The trial sequences are presented in Figure 3. Each trial began with a target cue display for 1s in the center of the screen. This was followed by a fixation display, which was presented for a period that varied unpredictably between three and four seconds. The stream of colored letters was then shown in the central location. The stream consisted of 16 letters. Each letter in the stream was displayed for 120 ms.The target letter randomly appeared in positions 6 through 11. The distractor border could change colors to match the target color, (same-color distractor), to a color other than the target color (different-color distractor) or stay gray (no distractor condition). The distractor could be presented at temporal lag positions 2 (presented two positions after the target,1 (one position before the target letter), 2 (presented two positions before the target letter), or 4 (four positions before the target letter).At the end of the stream, a “?” appeared. Participants were asked to enter the letter they think appeared in the target color. The response was entered by pressing that letter on a keyboard. Participants pressed the spacebar to submit their response and move on to the next trial.

The practice session consisted of 10 practice trials. Any questions about the experiment were answered during this time. Following the practice trials, participants completed 9 blocks of 42 trials, totaling 378 trials. This was made up of 168 same-color distractor trials (42 at each lag), 168 different-color distractor trials (42 at each lag), and 42 no distractor trials, appearing in random order, with the restriction that the same color could not be repeated on consecutive trials. Target color and target position were factorially crossed with each distractor condition and lag condition.

Results

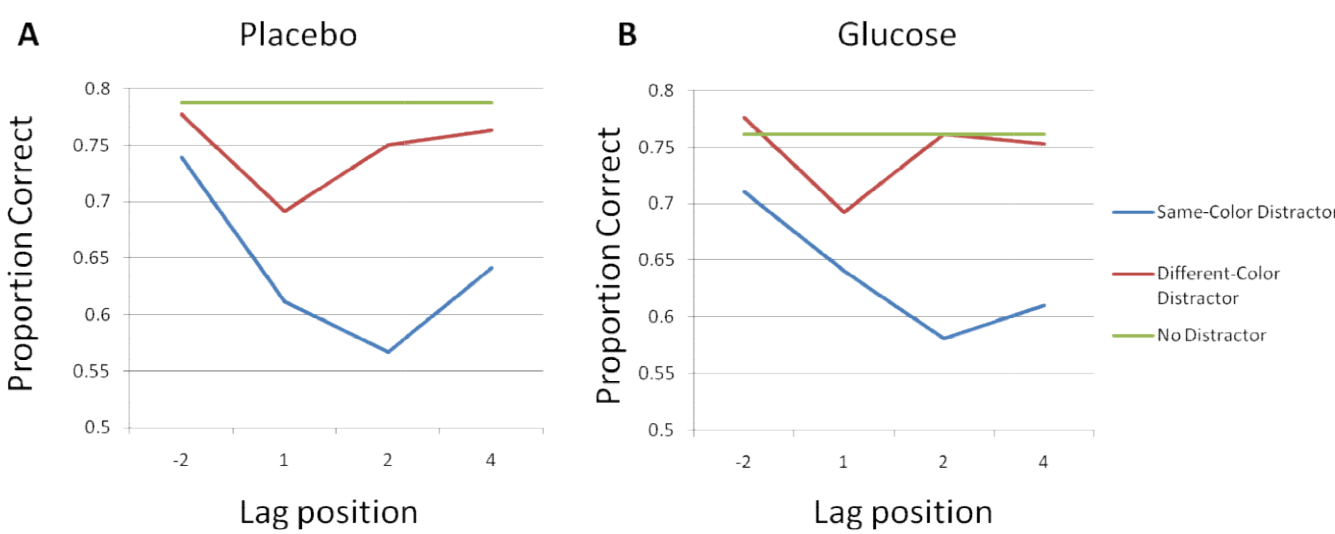

*Figure 4.*Average accuracy in the same-color, different-color, and no distractor conditions at each lag. **A:**Placebo Condition **B**: Glucose Condition

Mean accuracy was collated across each drink x distractor x lag conditions, and the data are presented in Figure 4. At first we examined whether the pattern of distractor interference overtime varied across the glucose and placebo conditions. We ran a 2 (drink condition: glucose drink versus placebo drink) by 2 (distractor: same-colored distractor versus different-colored distractor) by 4 (lag conditions: -2,1,2,4)within-subjects ANOVA. Because there were no lag positions in the no-distractor condition, this condition was not included in this analysis. The results indicate a main effect of distractor condition ($F(2, 36) = 55.097$, $p < .001$, $\eta_p^2 = .754$).This demonstrates that the variability in distractor conditions presented had a significant effect on accuracy, with the same-color distractor condition yielding the lowest accuracy rates. There was also a main effect of lag position ($F(3,54) = 9.88$, $p < .001$ $\eta_p^2 = .354$). In addition, there was a significant interaction between distractor condition and lag, ($F(3, 54) = 9.177$, $p < .001$, $\eta_p^2 = .338$) indicating that while the difference between same-color distractor and different-color distractor was relatively small at lag -2, the same distractor was relatively small at lag -2, the same distractor color had a larger effect relative to the different-colored distractor at lags 1, which is consistent with a contingent blink. Critically, we found that there was no main effect of drink ($p = 0.940$) and drink did not interact with either distractor condition or lag positions in either the two way interactions or in the three way interactions. This indicates that there is no difference between how glucose and placebo affect accuracy in either distractor condition or lag position. The contingent blink had the same strength and duration across both glucose and placebo conditions.

Finally, we ran a simple effect analyses to determine the conditions in which a contingent blink was present. We compared each lag x distractor x drink conditions to the baseline, no-distractor condition, using a paired samples t-test with a Holm-Bonferroni correction to control family-wise error rate (Holm, 1979). We reported the adjusted p-values in this. The analyses revealed that in both glucose and placebo condition, accuracy was significantly impaired at lags 1, 2 and 4 in the same-color condition (all *p*s< .012). This is consistent with Folk, et al.'s (2008) finding that a same-color distractor captures attention and impairs target identification. The effects were not significant for the same-color distractor condition at a lag -2 in the glucose condition and placebo condition (*ps*> .28). For the different-color distractor condition, accuracy was significantly lower at lag 1 in the placebo condition ($t(18)= 7.82$, $p = .014$), and this was in the same direction, but not significant in the glucose condition ($p=.29$). This effect was inconsistent with Folk, et al.'s (2008) experiment in that different-color distractors did not capture attention at any lag position. Different-color distractors did not capture attention at any other lags (all *p*s = 1.00 when adjusted using Holm-Bonferroni correction).

Discussion

The overall aim of this study was to examine whether glucose consumption affects attentional control. To do this, we conducted a double-blind, within-subjects experiment in which participants consumed a glucose drink and a placebo drink during different sessions and we observed the effects of glucose relative to placebo on an RSVP task. We made two main predictions. The first prediction was that glucose would enhance performance and cause rapid disengagement from distractors, allowing accuracy to return to baseline more quickly. The alternative prediction was that glucose would cause stronger engagement with distractors which would worsen accuracy. This study found no effect of additional glucose consumption on attentional control. Inconsistent with hypothesis 1, participants were not able to voluntarily disengage attention more rapidly from task-relevant distractors after consuming a glucose drink. The data reflects this because there is no significant difference in accuracy between drink conditions in the same-color distractor condition lag 4, which follows the contingent blink at lag 2. Further, inconsistent with hypothesis 2, glucose did not cause stronger engagement with distractor. There was no difference in accuracy between glucose and placebo conditions in the contingent blink, reflected in the same-color distractor condition at lag 2.

Some experiments found that glucose consumption decreased reaction time on the Stroop task (Brandt et al., 2013), but this effect was not shown in other experiments (Benton et al., 1993). Our experiment is consistent with Benton et al.'s (1993) experiment in that there is no effect of glucose consumption on attentional control.

These results are consistent with a growing number of recent papers questioning the positive effects of glucose on cognition. For example, in the literature on self-control, it had previously been shown that self-control depletes glucose, which indicates that self-control may depend on glucose availability (Galliot & Baumeister, 2007). However more recent studies argue that there is not such a simple bidirectional relationship between glucose consumption and performance and the relationship may be much more complex (Kurzban, 2010). They provide evidence to suggest glucose levels may not be depleted following a self-control task compared to before the task is performed.

This questions whether glucose availability is a constraint on performance or if glucose is reduced in only some tasks.

Our results suggest that in healthy populations, glucose consumption does not affect attentional control. However, we note that this experiment was conducted in a society in which food is readily available. Despite having fasted for at least 2 hours prior to the experiment, our participants' blood glucose levels may still have been close to ceiling, leaving no room for additional glucose to modulate attentional control. Another possible explanation is that attentional control may employ glucose only when this resource is available. However, in the absence of additional glucose, the body may be able to compensate for the lack of glucose. It may do this by decreasing the allocation of an alternate resource to other functions. This may create a sufficient resource which would be available for attentional control.Thus, there would still be sufficient resources available to maintain effective attentional control. While attentional control in populations with healthy glucose metabolism may not be influenced by additional glucose consumption, it may have a significant effect on cognition in populations with impaired glucose regulation. For example, non-diabetic populations with impaired glucose tolerance and impaired fasting glucose have impaired performance on a Stroop task (Gluck et al, 2013), suggesting that glucose regulation affects attentional control.

In relation to the attention literature, the current results replicate the standard findings of the contingent blink paradigm that attention is captured by a same-color distractor and interferes with performance. Interestingly, a blink also arose at lag 1 of the different color distractor condition, which is not consistent with attentional capture. In contrast to previous studies such as in Folk et al. (2008), in which the target color remained constant across the entire experiment, the current experiment presented targets in seven different colors and required switching target color on every trial. This frequent change in colors required participants to rapidly switch attentional control settings (Vickery, King, & Jiang, 2005; Lien, Ruthruff, &Naybr, 2014). This implied that when people must switch frequently between attentional control settings, their ability to allocate attention to the intended target is diminished. However, performance recovered by lag 2. This may indicate that the attentional control system is able to recover from a different-color distractor very quickly.

Limitations

One limitation of the current study concerns the amount of glucose given to participants. There is considerable variability across studies examining the effects of glucose on cognition in the amount of glucose consumed and the artificial sweetener used. In one experiment, participants consumed up to 75 g of glucose (Benton, et. al., 1994) and other experiments used only 25g of glucose (Brandt, et. al., 2013; Foster, et. al., 1998). Our experiment fell somewhere between the two using 39g of glucose. Some studies have indicated that 25g of glucose is sufficient to modulate cognitive functions, such as memory (Scholey, Harper, & Kennedy, 2001; Kennedy &Scholey, 2000).Our study used more than 25g which may have been more an ideal for studying the effects of glucose consumption. Additionally, previous artificial sweeteners used in experiments include saccharin, aspartame, acesulfame K (Foster, Owens, & Parker, 1994; Foster; Lidder, Sunram, 1998). The different types of artificial sweetener contain varying amounts of glucose. In the current experiment, we used Splenda, which contains less than 5g of sucralose per packet. The inconsistency in glucose dose and presence of real glucose present in artificial sweetener ingredients may affect the observations of effects of glucose in cognition.

Another issue was our inability to perfectly control and measure blood glucose levels. In the current study, we asked participants to fast for at least 2 hours prior to the experiment. We relied on participants' self-report and it is possible some participants may not have fasted at all. Also, some studies have measured blood glucose over the course of the experiment (Birnie, Smallwood, Reay, &Riby, 2015). This has allowed researchers to measure participants' baseline glucose level and be able to compare this across time to confirm a successful blood glucose manipulation. The current study did not use these measurements, and so the variation in blood glucose level in participants could not be observed. Furthermore, many studies implemented a longer fasting periods. For example, Foster, et al. (1998) asked their participants to fast at least nine hours prior to the experiment. Some researchers have reported that 2 hours produced similar effects of glucose to overnight fasting on both blood-glucose levels and on memory performance (Sünram-Lee, Foster, Durlach, & Perez, 2001); nevertheless, it is possible that this duration was insufficient to produce a large decrement in blood glucose levels with our participants.

In summary, our study found no effect of glucose consumption on attentional control. This may indicate the advantages of consuming high caloric snacks may not be due to increased glucose availability. Rather, this improved performance may be due to individual's expectations. When we complete exams, glucose consumption may not enhance our ability to attend to only specific questions on a page. On the other hand, consuming high caloric snacks does not appear to impair performance, so snacking while studying might not be detrimental to test performance.

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